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OPTIMIZATION OF LEVELS OF GUMS FOR IMPROVING PHYSICAL PROPERTIES OF YEAST LEAVENED BREAD USING RESPONSE SURFACE METHODOLOGY

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In present research work, the levels and combinations of gums were optimized by using response surface methodology (RSM) to prepare bread with better properties. For this purpose, Guargum, Xanthan gum, Carboxy Methyl Cellulose (CMC) were added in different levels and combinations. Effect of gums on the rheological properties of premix (combination of flour and gums) their impact on the physical properties of the bead was observed. Response Surface Methodology (RSM) was applied to estimate the responses of independent variables. The responses for farinographic characteristics from Box Behnken Design (BBD) showed significant effect of variables. However, linear terms of variables did not affect the farinographic characteristics considerably except degree of softening. The results regarding physical properties of the flour revealed that the regression coefficients as well as correlation coefficients related to the physical properties of bread like texture, volume, water activity and weight under the influence of independent variables were sufficient for a well fitted response surface model. The effects of linear terms, quadratic terms and their interaction of independent variables showed significant effects on physical properties especially volume of bread during storage. For the target values of farinographic and physical properties of bread, the optimized variable levels of gums were 0.501% (*Guargum*), 0.504% (*Xanthan gum*) and 0.481% (CMC).
Keywords: Farinograph, texture, dough consistency, hydrocolloids.

INTRODUCTION

Most commonly consumed food grain in the world is wheat. The wheat is the major dietary energy and protein for those peoples whose major diet contains cereals and cereal products. Among leading wheat producing countries, Pakistan is one of them Allah *et al.* (2016). Pakistan is producing 2% of the total wheat produced all over the world (Anjum and Walker, 2000). Several wheat varieties cultivated in all the provinces of Pakistan and are ground into flour to produce various products depending upon the quality of the flour. Therefore, the scientists and researchers are continuously engaged in production of wheat flour per the requirements which can be achieved through removing basic nutritional deficiencies (Akerberg and Zacchi, 2000. The wheat in Pakistan is consumed in various forms like Chapatti, Nan, Biscuits, Cookies, Pratha, Bakarkhani and Bread. Bread being perishable product bears a very short Shelf life. Bread quality is dependent upon various factors like chemical composition of Wheat flour. Due to the addition of various approved food additives the functional properties of wheat flour may be changed. The food additives like various stabilizers and emulsifiers may be used in its manufacturing to enhance shelf stability and improve texture along with softness. On other hand, because of various hydrocolloids on wheat flour starch synergistic interaction occurs and the intensity of the reaction is depending upon the nature and quantity of the gum being used as hydrocolloid (Eidam *et al.*, 1995). There are various uses of hydrocolloids in many of foods and these serve as thickening, gelling and stabilizing agents. The main purpose of using gums in foods is due to their ability to bind water and specially to produce those foods that provide low-calories foods (Rosell *et al.*, 2001). Due to the application of hydrocolloids in the production of various foods the water retaining ability and shelf stability along with products freshness is enhanced when it is stored for a long time (Funami *et al.*, 2005).

Although research work has been conducted on the use of hydrocolloids in its manufacturing, however negligible or very little work has been conducted on the utilization of a blend of these food additives (different combination of additives). Moreover, due to advancement new hydrocolloids are being introduced in the market which must be investigated for their usage in the food industry. Keeping in view the significance of these food additives (Gums) in baking industry and market demand, the present study was designed to evaluate the suitability of commercially available hydrocolloids in bread making and to investigate the effect of these additives on the quality and shelf life of the bread, Production of bread by using different hydrocolloids and emulsifiers in different combinations, to optimize the level of hydrocolloids and emulsifiers using response surface methodology and to study the effect of hydrocolloids and emulsifiers on functional/rheological properties of wheat flour.

MATERIALS AND METHODS

The current research work was conducted on optimization and characterization of gums for improved quality and shelf stability of yeast leaved bread using response surface methodology. For this purpose, the bread was prepared at Safina Foods (Merit Bread) Private Limited, 20 km GT road Kala Shah Kaku, Lahore (Pakistan) and then analyses was conducted at National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan, Institute of Food Science and Nutrition, University of Sargodha, Sargodha, Pakistan and Ayub Agriculture Research Institute, Faisalabad, Pakistan.

Along with these ingredients, different levels and combinations of gums were used for preparation of the bread. These levels and combinations of various gums were selected through response surface methodology (RSM) after preliminary trials on levels of gums are given in Table 1.

Table 1. Treatment plan for gums.

Treatments	Guargum (%)	Xanthan Gum (%)	CMC (%)
1	0.45	0.45	0.45
2	0.30	0.45	0.30
3	0.30	0.45	0.60
4	0.60	0.45	0.30
5	0.60	0.45	0.60
6	0.45	0.45	0.45
7	0.30	0.60	0.45
8	0.45	0.60	0.60
9	0.45	0.30	0.60
10	0.45	0.45	0.45
11	0.60	0.60	0.45
12	0.45	0.30	0.30
13	0.30	0.30	0.45
14	0.60	0.30	0.45
15	0.45	0.60	0.30

The yeast leavened bread was prepared with the following recipe Pyler *et al.* (1988).

Analysis of flour, premix and bread**:** The wheat flour as well as premixes (mixture of wheat flour and additives as per treatments) was subjected to rheological studies (farinograph) according to the methods recommended by AACC (2000). The bread was stored at room temperature in polypropylene bags and was evaluated for proximate composition (moisture, protein, fat, ash and NFE) by following the methods as recommended by AACC (2000). Texture of bread was determined at 1st and 6th day of storage using a texture analyzer as recommended by Rahman *et al*. (2005). For this purpose bread was analyzed on (Model TA-XT2 plus, Microsystems Surrey, UK) by using 5 kg Load cells and texture expert program version 4.0.9.0.

Recipe of bread

Ingredients	Percent
Flour	100.0
Water	60.0
Sugar	2.0
Salt	2.0
Yeast	1.0
Fat	2.0

The loaf volume at 1st and 6th day of storage was measured using the rapeseed displacement method. Each loaf was put in a container and covered with rapeseed to totally fill the container. Then the loaf was removed and the loaf volume was calculated by subtracting the volume of rapeseed from the total volume 7. Water activity at 1st and 6th day of storage was determined by using an electronic hygropalm water activity meter (Model. Aw-Win, Rotronic, equipped with a Karl-Fast probe) according to the method as described by Rahman *et al*. (2005). Weight of bread at 1st and 6th day of storage was also determined by using an electronic balance Shimadzu, japan. The results were statistically analyzed by using Analysis of Variance Technique. The Minitab statistical software (Minitab Inc. Quality plaza, 1829 Pine Hall Rd. State College, PA. 16801. United States) was used for optimization studies.

Table 2. Score sheet for sensorial characteristics of yeast raised bread treatments.

HARACTERISTICS	
EXTERNAL	
Volume	10
Colour of Crust	06
Evenness of Bake	03
Symmetry of Form	04
Character of Crust	04
Break and Shred	03
Total	30
INTERNAL	
Grain	13
Colour of Crumb	10
Aroma	09
Taste	18
Mastication	05
Texture	15
Total	70
Grand Total	100

RESULTS AND DISCUSSION

Proximate composition of wheat flour**:** The proximate composition of wheat flour revealed that it contained moisture

(12.54±0.03%), crude protein (13.30±0.26%), crude fiber (0.65±0.02%), crude fat (1.43±0.02%), ash (0.48±0.01%), and nitrogen free extract (NFE) (71.60±0.22%) as shown in Table 3.

Table 3. Proximate composition of wheat flour (%).

Parameter	% Value
Moisture	12.54±0.03
Crude Protein	13.30±0.26
Crude Fiber	0.65±0.02
Crude Fat	1.43±0.02
Ash	0.48±0.01
NFE	71.60±0.22

Farinographic characteristics of flour**:** The responses for farinographic characteristics from Box Behnken Design (BBD) were fitted with second order polynomial equations (Table 4a, b). The statistical analysis by applying analysis of variance technique to the full regression of model (Table 5a, b) showed significant effect of variables (guargum, xanthan gum and CMC). The linear terms of variables effect the farinographic characteristics considerably except water absorption, whereas quadratic terms of variables (guargum, xanthan gum and CMC) showed highly significant effect. When interaction of these terms was studied, it was found negative in most of responses. The coefficients of determination (R^2) were studied as 94.0% (consistency), 81.50% (water absorption 500U), 64.10% (water absorption at 14%), 88.40% (development time), 90.80% (stability),

Table 4a. Response surface regression (analysis of variance) for farinographic studies.

Sources of variation	DF	Mean squares			
		Consistency (FU)	Water absorption (500U)	Water absorption (14.0%)	Development time (min)
Regression	9	131.963**	0.10588	0.01101	0.66100*
Linear	3	291.300***	0.15636	0.01642	1.38897**
Square	3	343.750***	0.29675**	0.02958	1.55299**
Interaction	3	47.904	0.00731	0.00119	0.35604
Residual Error	5	15.073	0.04324	0.01111	0.15588

* = Significant (P<0.10); ** = Significant (P<0.05); *** = Significant (P<0.01)

Table 4b. Response surface regression (analysis of variance) for farinographic studies.

SOV	DF	Mean squares			
		Stability (min)	Degree of softening (FU)	Degree of softening (FU ICC)	Farinograph quality No.
Regression	9	0.29517**	146.119***	124.650**	64.119
Linear	3	0.60916**	205.646***	191.312**	144.862**
Square	3	0.62313**	204.741***	233.367**	159.498**
Interaction	3	0.10542	61.808**	48.833	24.230
Residual Error	5	0.05386	5.998	19.150	23.991

** = Significant (P<0.05); *** = Significant (P<0.01)

Table 5a. Regression coefficients for the models representing as a function of variations in the explanatory variables.

Terms of model equations	Consistency (FU)	Water absorption (500U)	Water absorption (14.0%)	Development time (min)
Constant	208.2***	48.98***	50.329***	-20.34***
Guargum (X_1)	688.7***	9.91	2.557	34.33**
Xanthan (X_2)	362.8**	11.89*	5.018	37.38**
CMC (X_3)	358.9**	13.43*	3.212	34.54**
X_1^2	-588.3***	-12.34**	-2.433	-24.17**
X_2^2	-378.3***	-13.59**	-6.100*	-39.17***
X_3^2	-373.9***	-14.56**	-3.122	-26.94*
$X_1 \times X_2$	-166.7	2.22	0.356	-5.56
$X_1 \times X_3$	-168.9	0.98	-1.111	-22.22*
$X_2 \times X_3$	121.1	-2.22	0.644	1.67
R^2 (%)	94.0	81.50	64.10	88.40

* = Significant (P<0.10); ** = Significant (P<0.05); *** = Significant (P<0.01)

Table 5b. Regression coefficients for the models representing as a function of variations in the explanatory variables

Terms of model equations	Stability (min)	Degree of softening (FU)	Degree of softening (FU ICC)	Ferinograph quality No.
Constant	-12.41***	-177.4***	-190.5**	-181.2**
Guargum (X_1)	20.47**	383.9***	374.2**	444.5**
Xanthan (X_2)	28.88***	218.2**	289.2**	309.7*
CMC (X_3)	18.87**	562.7***	523.3***	299.5*
X_1^2	-15.80**	-279.8***	-344.4**	-351.5**
X_2^2	-23.57***	-294.3***	-366.7**	-295.9**
X_3^2	-18.46**	-457.6***	-422.2***	-289.3**
X_1 x X_2	-11.22*	55.6	133.3	-137.8
X_1 x X_3	-3.89	-292.2***	-211.1*	-122.2
X_2 x X_3	-3.89	-55.6	-100.0	44.4
R^2 (%)	90.80	97.80	82.80	

* = Significant (P<0.10); ** = Significant (P<0.05); *** = Significant (P<0.01)

97.80% (degree of softening), 92.10% (degree of softening) and 82.80% (farinograph quality no.) were enough for well fitted response models. The data showed that guargum (X_1), xanthan gum (X_2) and CMC (X_3) contributed towards change in farinographic characteristics of flour. The response optimization function of Minitab program was commissioned to reach a solution for optimum level to achieve desired responses. The effects of these variables are shown through three dimensional response surface plots. These graphs indicated a clear effect of explanatory variables.

For the target value of (500U) consistency, the optimized variable levels were Guargum 0.57%, Xanthan Gum 0.60% and CMC 0.60% (Fig. 1-3). For the target value of water absorption at 500 U (55.89), the optimized variable levels were Guargum 0.60%, Xanthan Gum 0.60% and CMC 0.60% (Fig. 4-6) and for water absorption at 14% moisture level (52.78), Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.50% (Fig. 7-9) were found to be optimized levels.

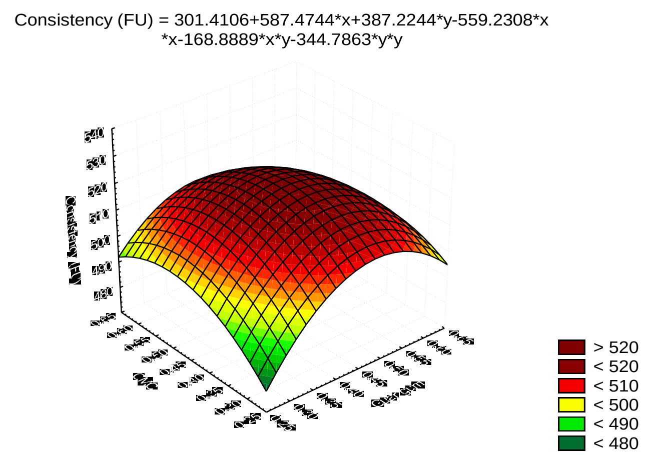

Figure 2. Effect of independent variables (X_1, X_3) on dough consistency (FU).

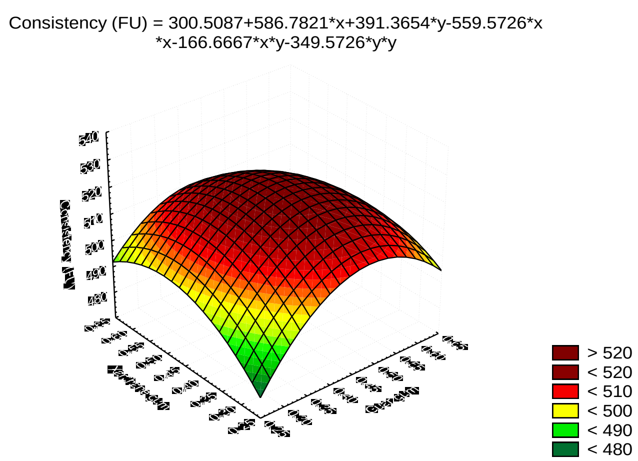

Figure 1. Effect of independent variables (X_1, X_2) on dough consistency (FU).

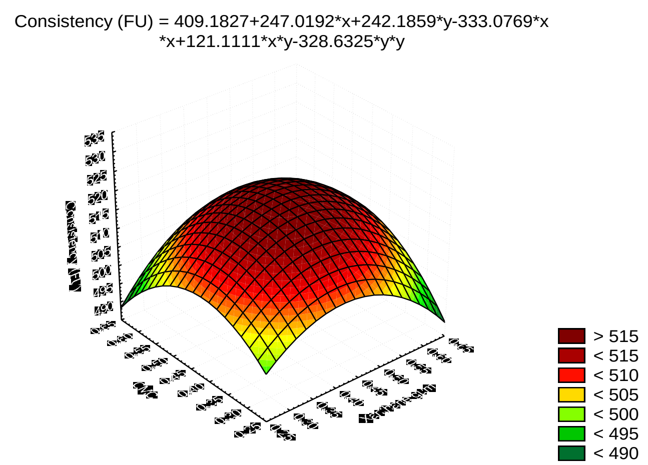

Figure 3. Effect of explanatory variables (X_2, X_3) on dough consistency (FU).

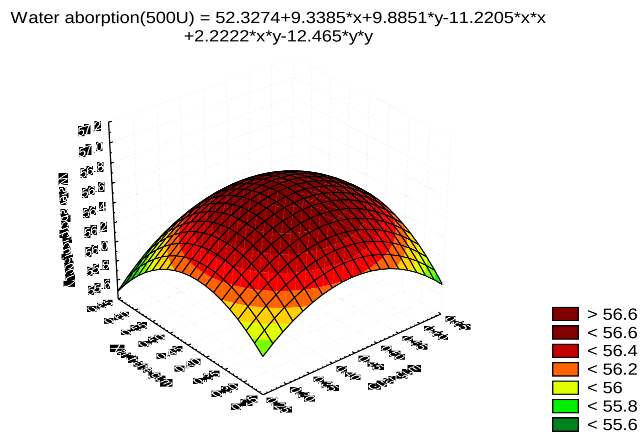

Figure 4. Effect of explanatory variables (X_1, X_2) on water absorption (500U)

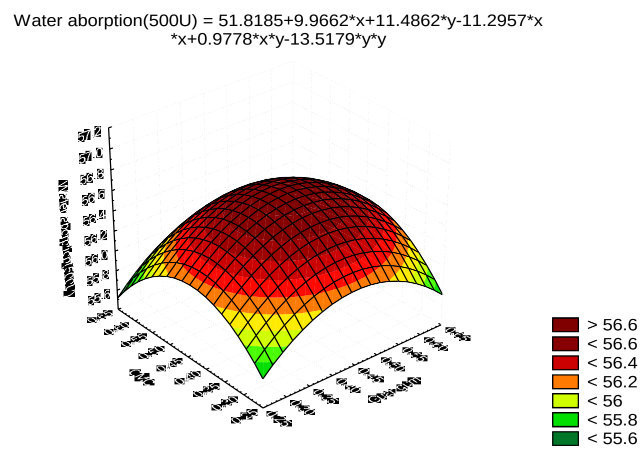

Figure 5. Effect of explanatory variables (X_1, X_3) on water absorption (500U).

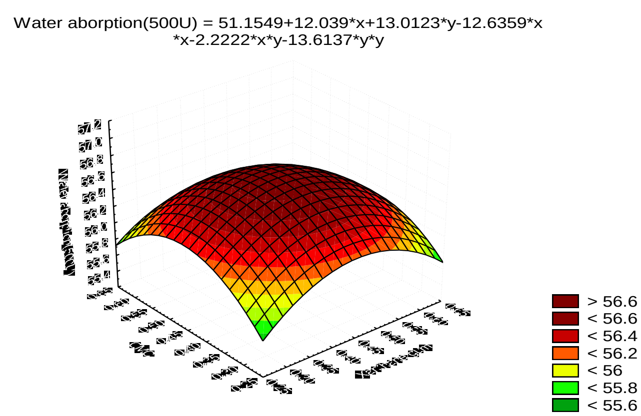

Figure 6. Effect of explanatory variables (X_2, X_3) on water absorption (500U).

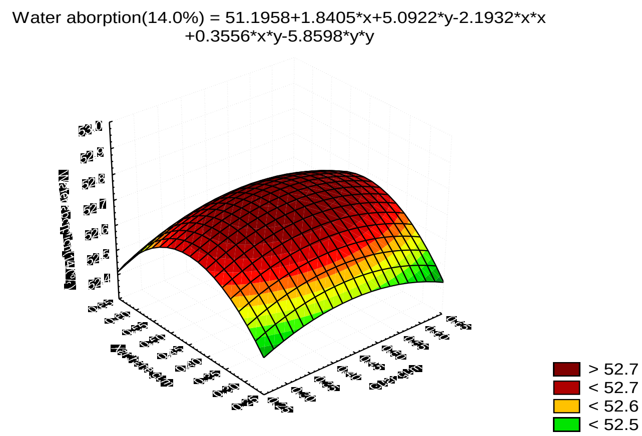

Figure 7. Effect of explanatory variables (X_1, X_2) on water absorption (14 %).

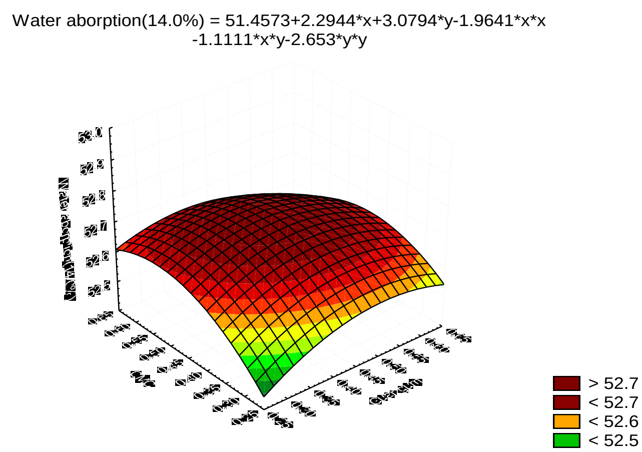

Figure 8. Effect of explanatory variables (X_1, X_3) on water absorption (14 %).

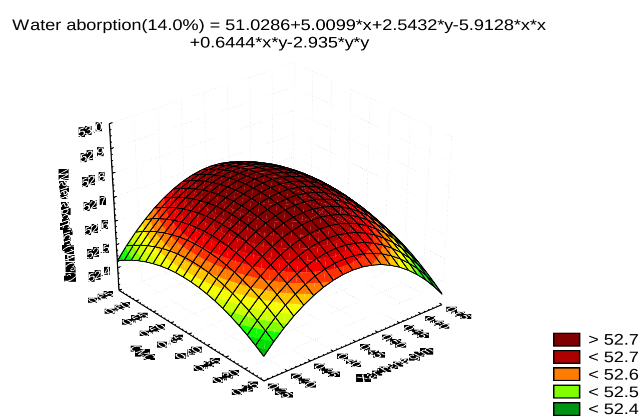

Figure 9. Effect of explanatory variables (X_2, X_3) on water absorption (14 %).

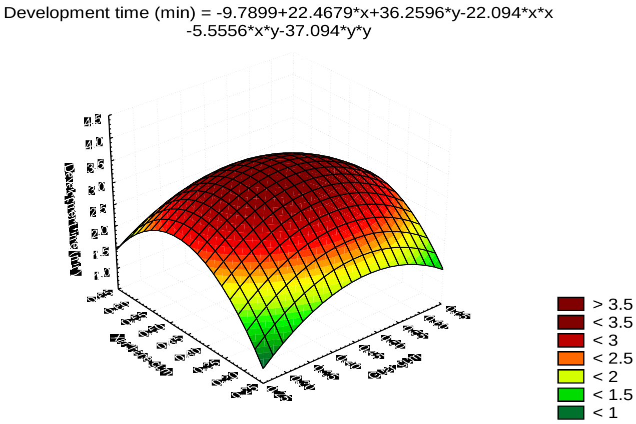

Figure 10. Effect of explanatory variables (X_1, X_2) on dough development time.

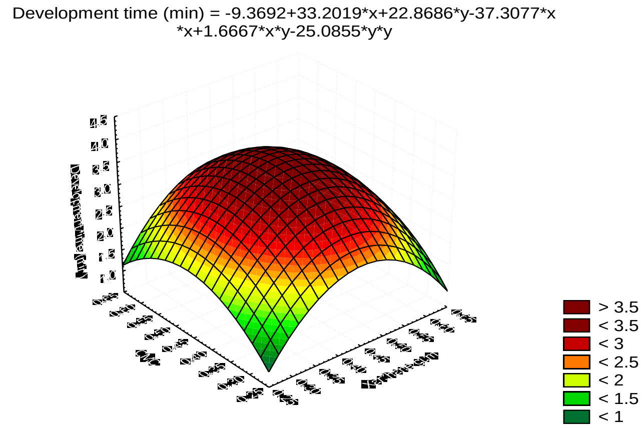

Figure 12. Effect of explanatory variables (X_2, X_3) on dough development time.

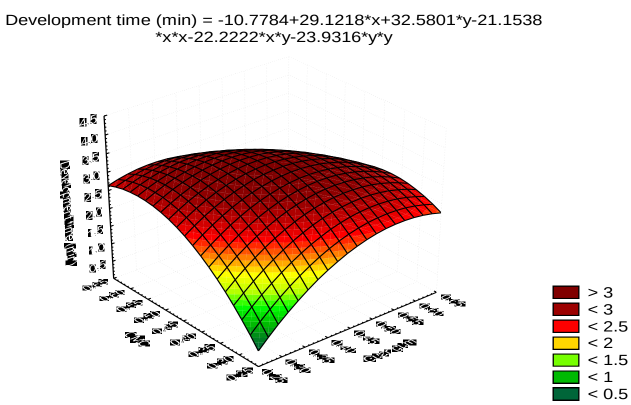

Figure 11. Effect of explanatory variables (X_1, X_3) on dough development time.

For the target value of dough development time (3.00 minutes), the optimized levels of variables were Guargum 0.50%, Xanthan Gum 0.53% and CMC 0.60% (Fig.10-12), for dough stability m (2.00) the optimized levels were Guargum 0.50%, Xanthan Gum 0.48% and CMC 0.60%, for degree of Softening; FU (70.00) the optimized levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.55%, for degree of softening; FUICC (70.00) the optimized levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.56% and for farinograph quality number (50.00) the optimized levels were found to be Guargum 0.50%, Xanthan Gum 0.54% and CMC 0.60%.

***Physical properties of bread*:** The regression coefficients are shown in (Table 6a, b and 7a, b) as well as correlation coefficients obtained for models related to the physical

Table 6a. Response surface regression (analysis of variance) for physical properties of bread.

SOV	DF	Mean squares			
		Texture (Day 1)	Texture (Day 6)	Volume (V)_Day 1	Volume (V)_Day 6
Regression	9	0.09153	0.20205**	10931	14447.8**
Linear	3	0.23010**	0.39285***	10108	26694.9***
Square	3	0.21862**	0.36498***	15119	32097.8***
Interaction	3	0.05284	0.14721**	6017	7179.1*
Residual Error	5	0.02968	0.02526	5198	1540.5

* = Significant (P<0.10); ** = Significant (P<0.05); *** = Significant (P<0.01)

Table 6b. Response surface regression (analysis of variance) for physical properties of bread.

SOV	DF	Mean squares			
		Weight (G)_Day 1	Weight (G)_Day 6	Water activity (Day 1)	Water activity (Day 6)
Regression	9	18.749	10.791	0.001376	0.002168
Linear	3	43.052*	21.604*	0.002498*	0.004349**
Square	3	41.326*	28.957*	0.002892**	0.003723*
Interaction	3	11.279	1.264	0.000194	0.000769
Residual Error	5	9.705	5.821	0.000483	0.000806

* = Significant (P<0.10); ** = Significant (P<0.05)

Table 7a. Regression coefficients for the models representing as a function of variations in the explanatory variables.

Terms of model equations	Texture (Day 1)	Texture (Day 6)	Volume (V) Day 1	Volume (V) Day 6
Constant	92.24***	94.40***	-552	-1470**
Guargum (X_1)	12.85**	14.61**	3783*	6769***
Xanthan (X_2)	17.87***	24.63***	1925	3673**
CMC (X_3)	10.99*	13.76**	2842	1783
X_1^2	-9.17*	-5.83	-3519*	-5809***
X_2^2	-16.38***	-22.54***	-3185	-4443***
X_3^2	-6.24	-9.78**	-2296	-2031*
X_1 x X_2	-2.81	-10.70**	1000	-1333
X_1 x X_3	-7.30	-10.04**	-2778	-2300**
X_2 x X_3	-4.13	-1.64	444	1889*
R^2 (%)	84.70	93.50	79.10	94.40

* = Significant (P<0.10); ** = Significant (P<0.05); *** = Significant (P<0.01)

Table 7b. Regression coefficients for the models representing as a function of variations in the explanatory variables.

Terms of model equations	Weight (G) Day 1	Weight (G) Day 6	Water activity (Day 1)	Water activity (Day 6)
Constant	106.3**	139.0***	0.055	-0.310
Guargum (X_1)	202.8**	157.6**	1.688**	1.987**
Xanthan (X_2)	236.3**	158.6**	1.713**	2.452**
CMC (X_3)	119.3	59.9	0.525	0.974
X_1^2	-133.3	-140.3*	-1.696**	-1.632*
X_2^2	-216.7**	-169.7**	-1.455**	-1.910**
X_3^2	-99.9	-59.2	-0.268	-0.583
X_1 x X_2	-103.3	-25.6	-0.211	-0.762
X_1 x X_3	-77.7	-33.1	-0.260	-0.556
X_2 x X_3	-0.0	11.1	-0.419	-0.500
R^2 (%)	77.70	76.90	83.70	82.90

* = Significant (P<0.10); ** = Significant (P<0.05)

properties of bread like texture, volume, water activity under the influence of independent variables (*guargum, xanthan* gum and CMC). The regression coefficients for these models (R^2) were sufficient for a well fitted response surface models. The effect of linear terms, quadratic terms and their interaction of independent variables showed significant effects on physical properties (except X_3) especially, texture and volume of bread at 6th day of storage period. The effects of independent parameters on physical properties of bread at 1st and 6th days of storage intervals through three dimensional response surface graphs. The results demonstrated that these variables contributed towards change in physical properties during storage. The graphs further indicated a clear effect of independent variables. The response optimization function of Minitab program was commissioned to reach a solution for optimum level to achieve desired responses.

For the target value of texture at day one (101.00), the optimized variable levels were Guargum 0.51%, Xanthan Gum 0.60% and CMC 0.60% and for the target value of texture at day six (105.84), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.37%. For the target value of volume at day one (1095.00), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.56% (Fig. 13) and for the target value of volume at day six (1173.57), the optimized variable levels were Guargum 0.49%, Xanthan Gum 0.49% and CMC 0.39% (Fig. 13).

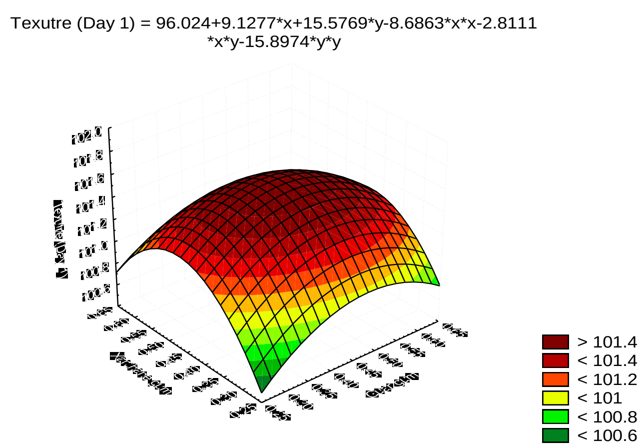

Figure 13. Effect of explanatory variables (X_1, X_2) on texture of bread during storage (at 1 day).

For the target value of weight at day one (228.70), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.40% (Fig. 14) and for the target value of weight at day six (223.36), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.41% (Fig. 14). For the target value of water activity at day one (0.95), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.35% (Fig. 15) and for the target value of water activity at day six (0.92), the optimized variable levels were Guargum 0.50%, Xanthan Gum 0.50% and CMC 0.36% (Fig. 15).

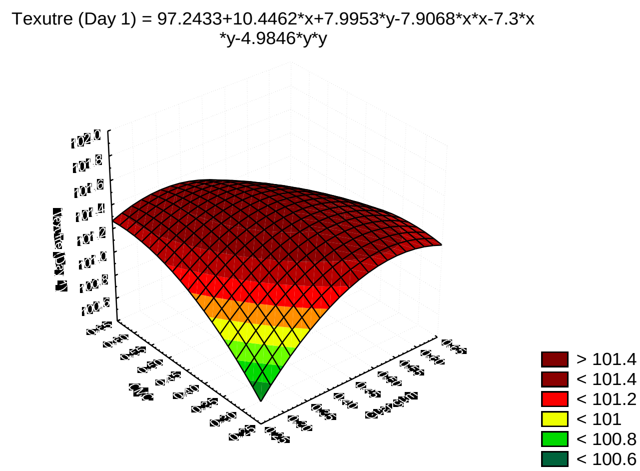

Figure 14. Effect of explanatory variables (X_1, X_3) on texture of bread during storage (at 1 day).

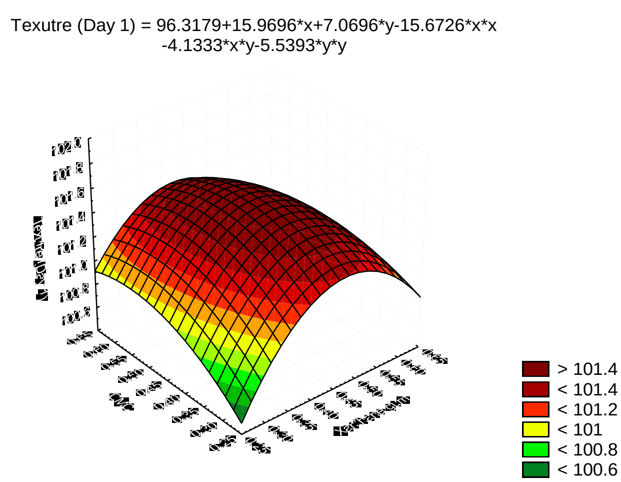

Figure 15. Effect of explanatory variables (X_2, X_3) on texture of bread during storage (at 1 day).

In this study, effect of independent variables (gums) was assessed on the physical properties of bread during storage period of 6 days. Response surface methodology, a statistical technique was applied to determine the true relationship between dependent and independent variables to find out regions of best response values (Steel *et al.*, 1997).

The texture, water activity and volume are feature of prime importance in bread physical quality parameters. The predicted values were in good agreement with the experimental values showing that the model could be used to predict and optimize the levels of gums. The regression coefficients for these models (R^2) were enough for the well fitted response surface. The surface plots for physical parameters at 1st and 6th days showed that the optimum levels of independent variables were used for achieving acceptable quality attributes for shelf stability of bread. The results indicated that each aspect of independent variables suggested different optimized levels which might be occurred due to different properties of gums (Rahmati *et al.*, 2014). These results are in agreement with previous findings. For the target values of farinographic and physical properties of bread, the optimized variable levels of gums were determined as follows:

The optimized levels for gums

Guargum (X_1)	:	0.5006%
Xanthan gum (X_2)	:	0.5045%
CMC (X_3)	:	0.4811%

The rheology of wheat flour and premix was improved due to the addition of hydrocolloids. Moreover, the results of current study clearly indicated that the overall quality of the bread was improved due to the addition of gums hydrocolloids.

The role of hydrocolloids as multifunctional ingredients in present research work showed that these enhanced the flexibility of dough, acted as fat replacer, good water retainer and good texturizing agent. The results are justified by the recommendations of Piga *et al.* (2005) who also reported the water retention and texture of the final product is significantly improved due to the addition of hydrocolloids.

In present study the dough handling properties were enhanced as well as the freshness and texture of bread along with the shelf life was improved due to the addition of hydrocolloids. The results are also justified by the findings of Gurkin (2002) who argued that due to the addition of hydrocolloids, the dough handling properties are improved with enhanced quality and shelf life of the bread. These results are justified by the findings of who reported that due the addition of emulsifiers the volume of bread was increased along with the oven spring (increased volume during baking), whiter color, finer crumb texture and longer shelf life.

The results are also justified by the findings of a number of other scientists who also reported that the rheology of flour, bread quality and shelf life is improved due to the addition of hydrocolloides and emulsifiers (Collar *et al.*, 2005; Gomez, 2004; Matuda *et al.*, 2005; Azizi and Rao, 2005; Mezger, 2006; Asghar *et al.*, 2007). However, the performance of these additives depends upon the type, concentration, food system and pH and temperature of the food system (Sahin and Ozdemir, 2004).

***Conclusion*:** It has been found that the physical properties during storage of bread could considerably be improved using (0.5006%) Guargum, (0.5045%) Xanthan gum, (0.4811%) CMC. Response surface methodology was observed as the best statistical tool to discriminate the interactive effects of independent variables.

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